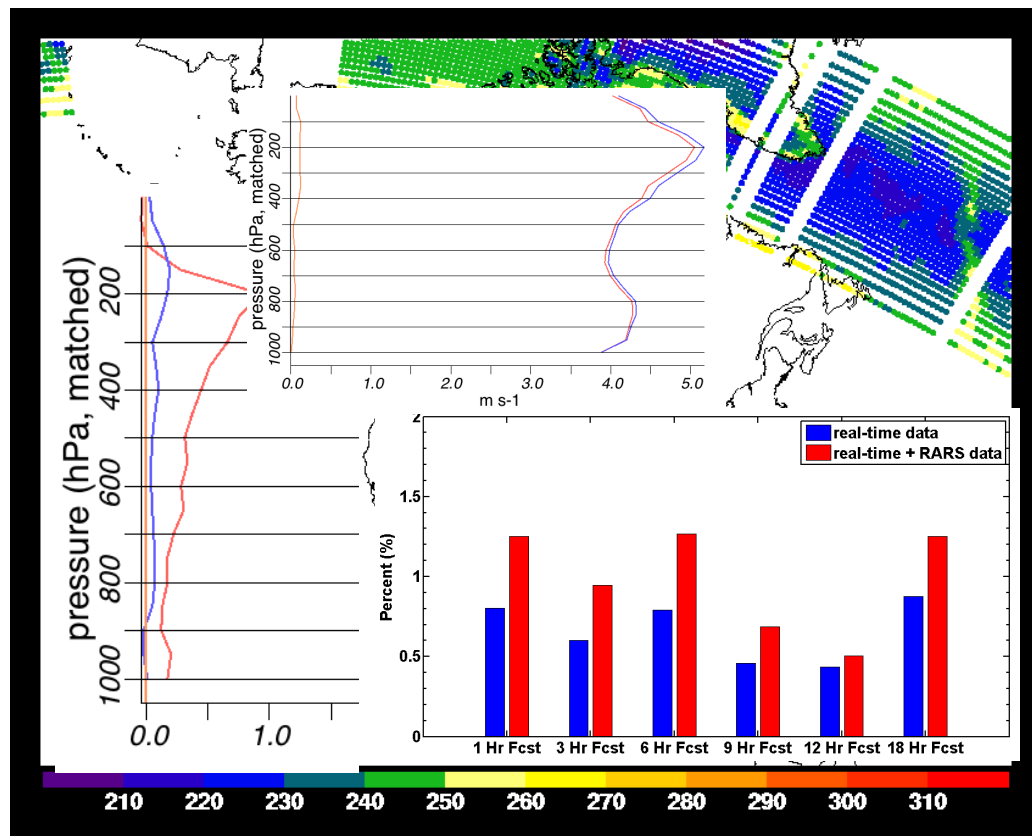


Evaluation of impact of satellite radiance data within the hybrid variational/EnKF Rapid Refresh data assimilation system

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Background on **Rapid Refresh/HRRR** *NOAA/NCEP's hourly updated models*

RAP version 1 -- NCEP since Spring 2012

- Key features for short-range “situational awareness” application (cloud analysis, radar-reflectivity assimilation)
- ➔ RAP/HRRR guidance for aviation, severe weather, energy applications

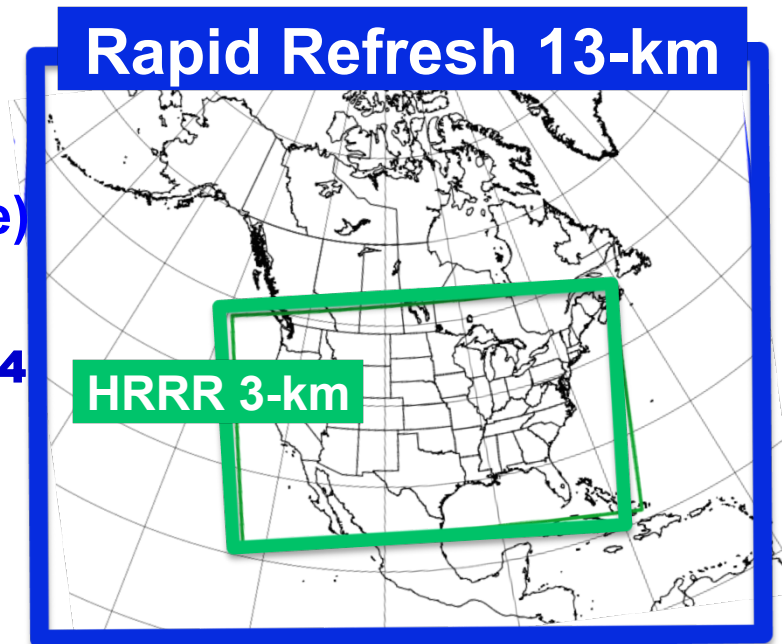
RAP version 2 -- implemented NCEP 25 Feb 2014

- Data assimilation enhancements (Hybrid – EnKF using global ensemble)

High-Resolution Rapid Refresh (HRRR) : NCEP implemented on 30 Sep. 2014

RAP version 3 -- planned implementation in June 2015

- ✓ radiance assimilation updates (focus of this talk)

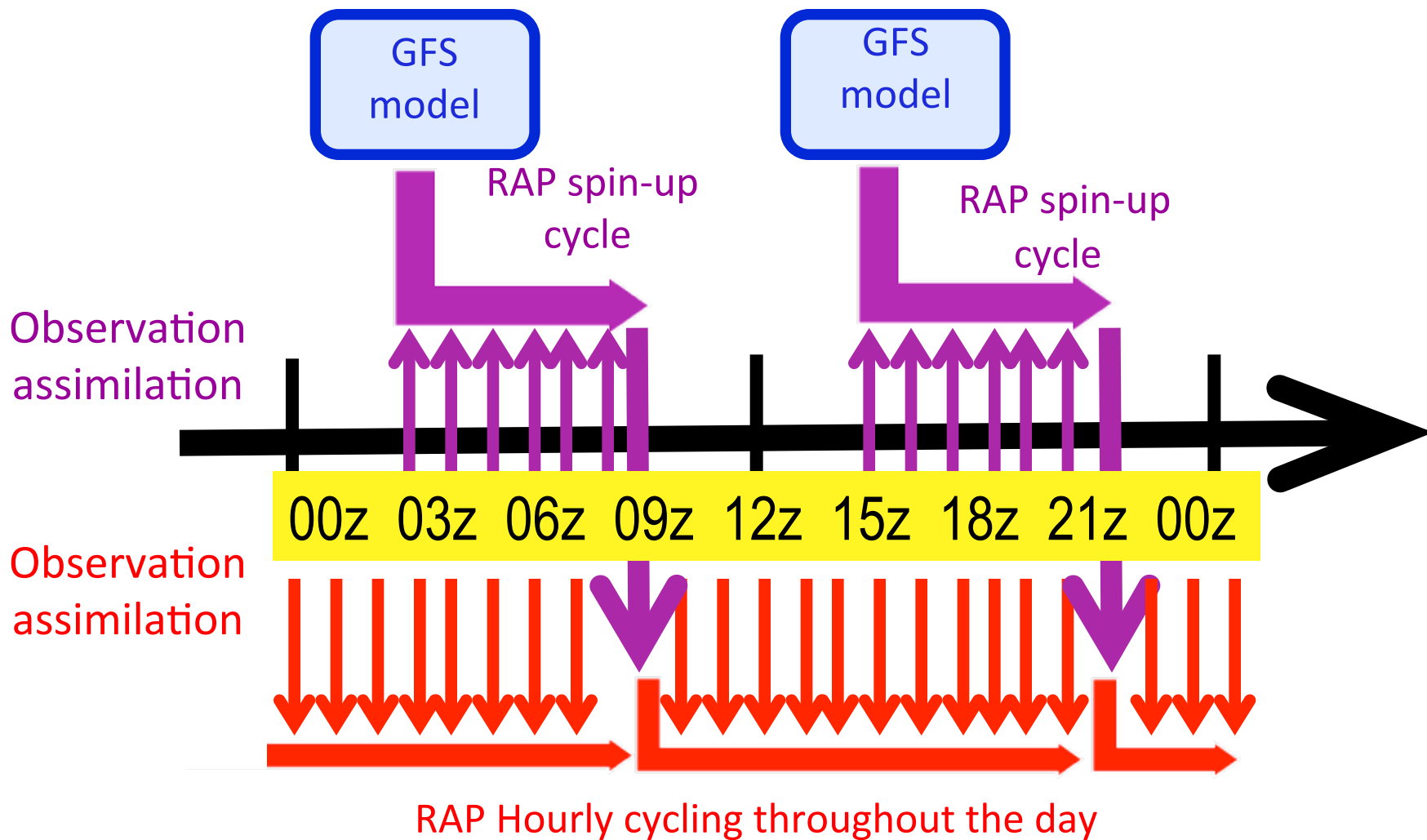




RAPv3: Observations used

Hourly Observation Type	Variables Observed	Observation Count
Rawinsonde	Temperature, Humidity, Wind, Pressure	120
Profiler – NOAA Network	Wind	~0
Profiler – 915 MHz	Wind, Virtual Temperature	20-30
Radar – VAD	Wind	125
Radar	Radial Velocity	125 radars
Radar reflectivity – CONUS	Rain, Snow, Hail	1,500,000
Lightning	(proxy reflectivity)	NLDN
Aircraft	Wind, Temperature	2,000 -15,000
Aircraft - WVSS	Humidity	0 - 800
Surface/METAR	Temperature, Moisture, Wind, Pressure, Clouds, Visibility, Weather	2200 - 2500
Surface/Mesonet	Temperature, Moisture, Wind	~5K-12K
Buoys/ships	Wind, Pressure	200 - 400
GOES AMVs	Wind	2000 - 4000
AMSU/HIRS/MHS/ GOES (RARS)	Radiances	5,000
GOES cloud-top press/temp	Cloud Top Height	100,000
GPS – Precipitable water	Humidity	260
WindSat Scatterometer	Winds	2,000 – 10,000 ³

Rapid Refresh Partial Cycling



- Hourly cycling of land surface model fields
- 6-hour spin-up cycle for hydrometeors, surface fields

Radiance Assimilation for RAP

Challenges for regional, rapid updating radiance assimilation

•Bias correction

- Sophisticated cycled predictive bias correction in GSI
- Spin-up period, complicated by non-uniform data coverage

•Channel Selection

- Many channels sense at levels near RAP model top (10 mb)
- Use of these high peaking channel can degrade forecast
- Jacobian / adjoint analysis to select channels for exclusion

•Data availability issues for real-time use

Rapid update regional models: short data cut-off, small domain

- Combined with large data latency → little data availability
- Complicates bias correction, partial cycle assimilation options
- Direct readout data has potential for real-time RAP

Radiance DA updates for RAPv3

(mid-2015 NCEP implementation)

- ◆ Implement the enhanced variational bias correction scheme (developed by EMC/NCEP) with cycling
- ◆ Remove some high-peaking channels to fit the model top of RAP, removes O₃ channels
- ◆ Include the direct readout (Regional ATOVS Retransmission Services(RARS)) data
- ◆ Include new sensors/data
 - ◆ GOES sounding data from **GOES-15**
 - ◆ AMSUA/MHS from **NOAA-19** and **METOP-B**;

Radiance data used for RAPv2

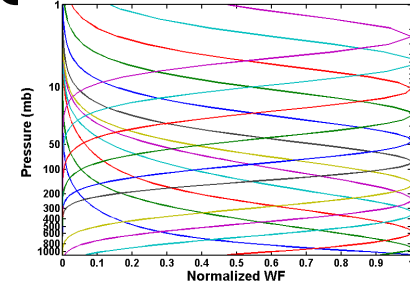
- **AMSUA** (used in operational RAP)
 - Temperature and moisture information
 - NOAA-15/18, METOP-A
- **MHS** (used in operational RAP)
 - Temperature and moisture information
 - NOAA-18, METOP-A
- **HIRS4** (used in operational RAP)
 - Temperature information
 - Moisture information (channels 10-12)
 - METOP-A

Radiance channels selected for RAPv3 (2015)

RARS
- NOAA-15/18/19, METOP-A/B

AMSU-A (remove high-peaking channels)

- NOAA-15: channels 1-10, 15;
- NOAA-18: channels 1-8, 10, 15;
- NOAA-19: channels 1-7, 9-10, 15;
- METOP-A: channels 1-6, 8-10, 15 (removed channel 8 on 26 Sep. 2014 per NCEP note) ;
- METOP-B: channels 1-10, 15;



HIRS4 (remove high-peaking and O₃ channels)

- METOP-A: channels: 4-8, 10-15;

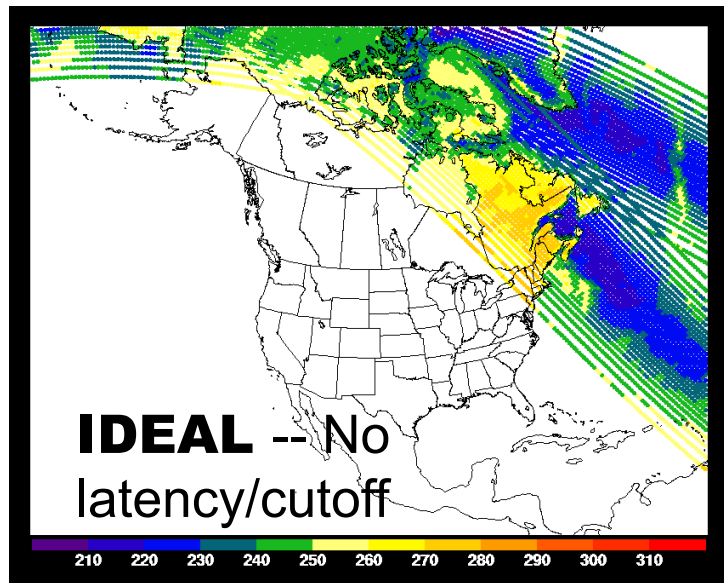
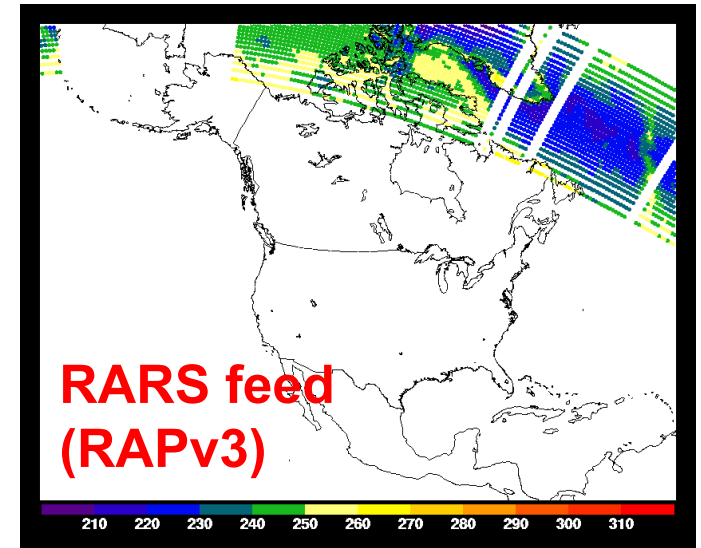
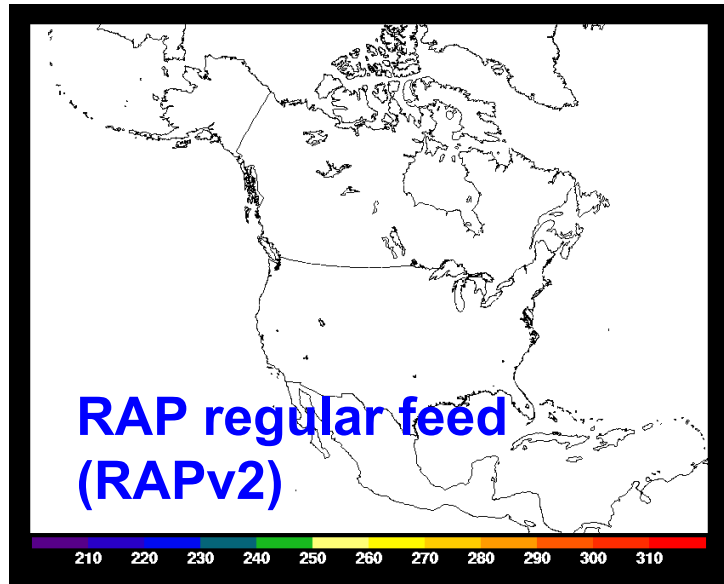
MHS

- NOAA-18/19, METOP-A/B : channels 1-5;

GOES (remove high-peaking and ozone channels)

- GOES-15 (sndrD1, sndrD2, sndrD3, sndrD4): channels 3-8, 10-15.

Real-Time data availability -- RARS

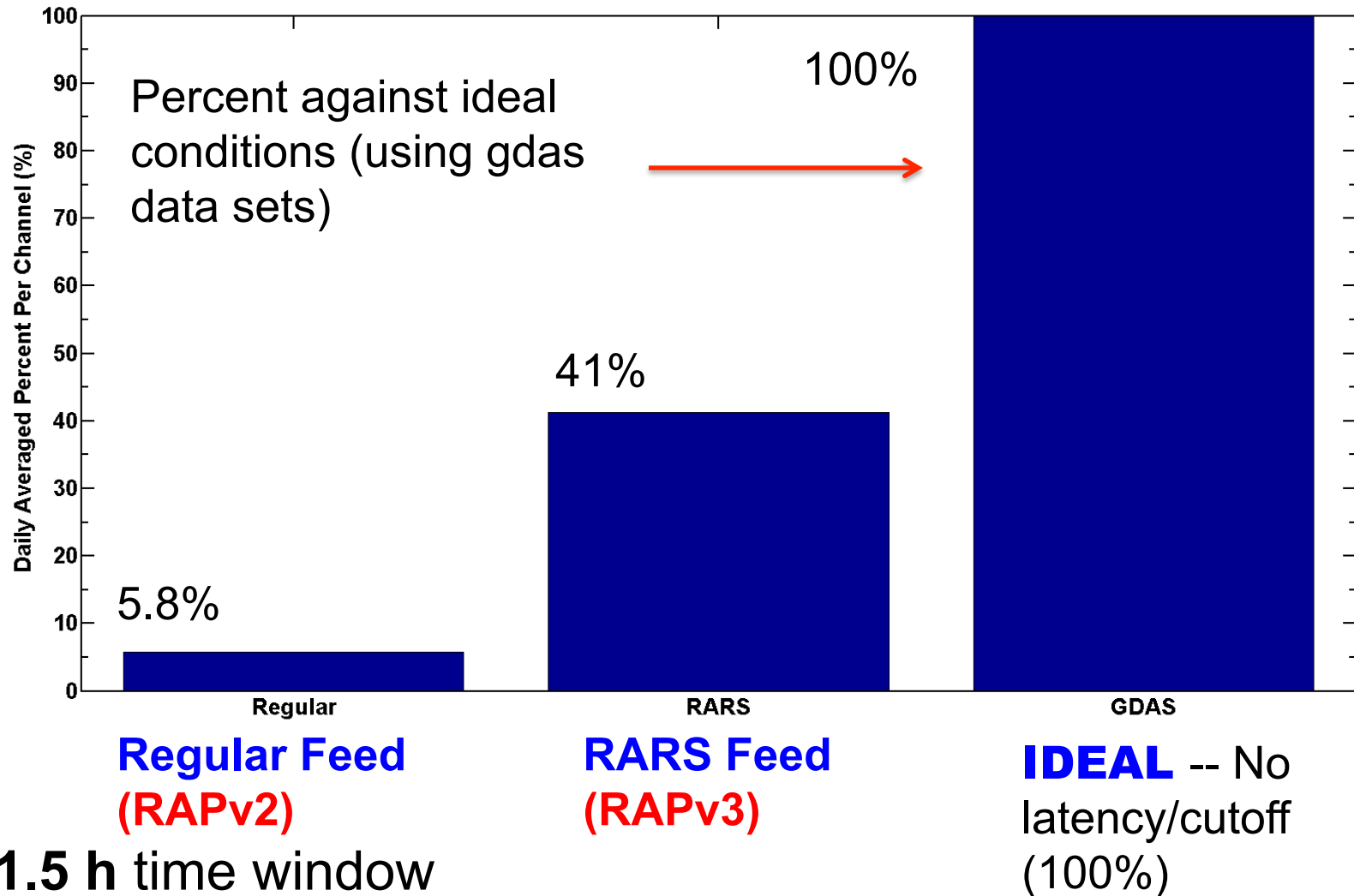


18Z May 29, 2013

+/- 1.5 h time
window

**AMSU-A channel 3 from
NOAA-18**

Daily averaged percent (%)

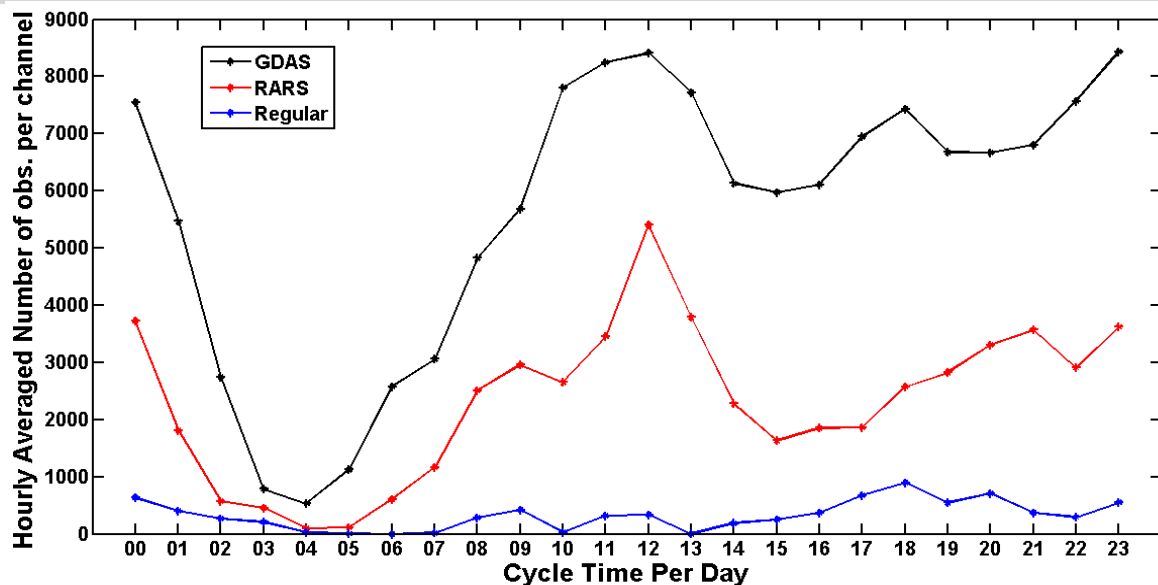


Averaged over one-month period (20130501-20130531)

AMSU-A channel 3 from NOAA-18

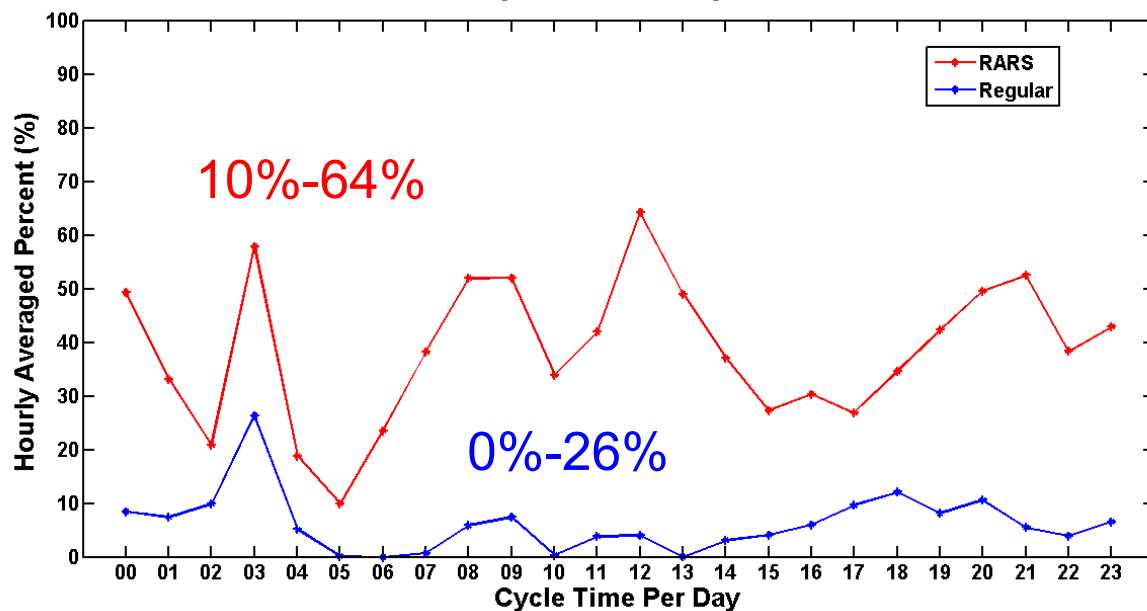
Hourly averaged observation number and hourly averaged observation % against GDAS

hourly averaged number per channel



Regular (RAPv2)
RARS (RAPv3)
GDAS

hourly averaged observation percent against GDAS

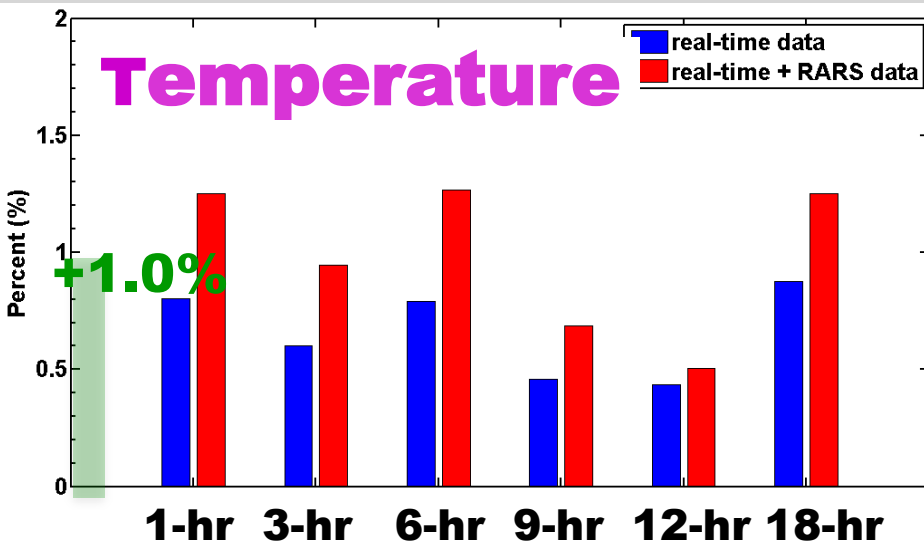


**AMSU-A
channel
3 from
NOAA-18**

Retrospective Experiments (RAPv3)

- **Control run (CNTL) – (conventional data only)**
 - 1-h cycling run, one-month retro run (May 01 – May 31 2013)
 - RAP Hybrid EnKF system
- **RAP radiance regular feed (limited availability)**
 - CNTL + RAP radiance regular feed data (amsua/mhs/hirs4/goes)
 - Including RAPv3 radiance updates except including RARS data
- **RARS data included (improved availability)**
 - CNTL+RAP radiance regular feed data + RARS data (RARS data for amsua/mhs)
 - Including all RAPv3 radiance updates

One-month retro % improvement from radiance DA

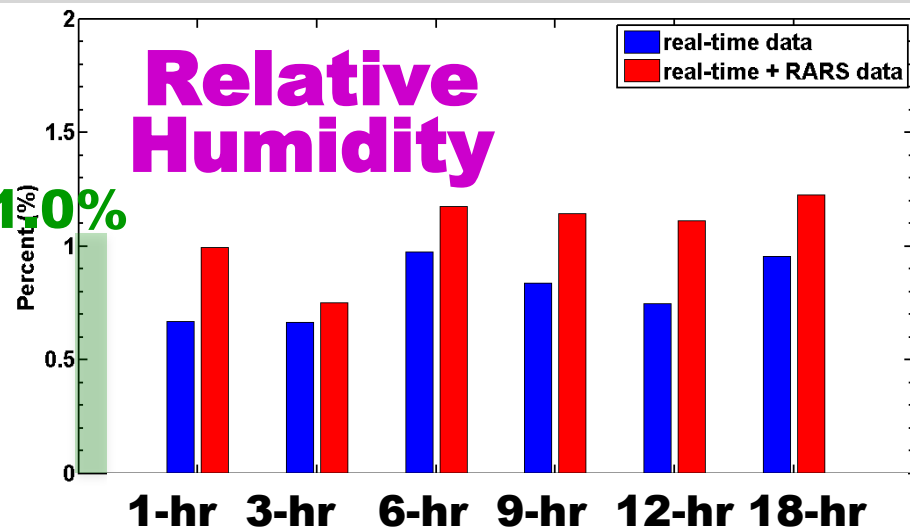
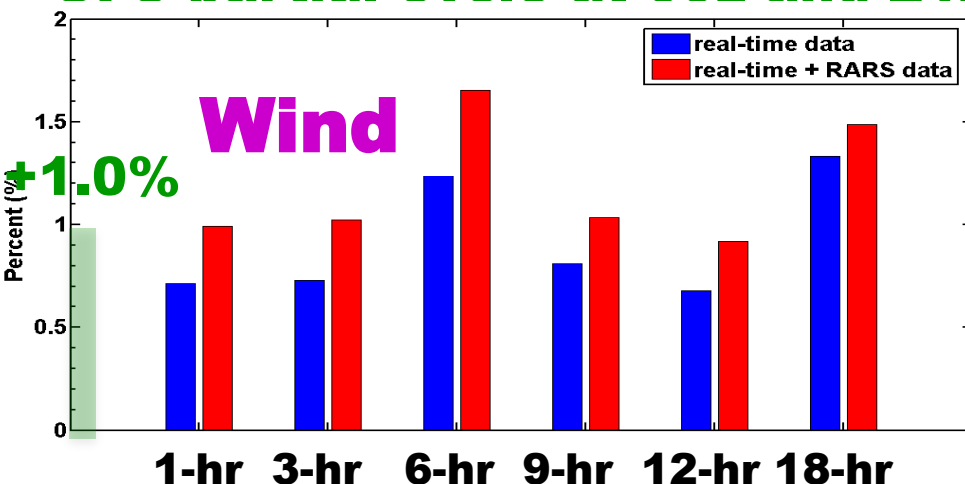


Init Hour 11,23z 9,21z 6,18z 3,15z 0,12z 18,6z

Fcst length 1 3 6 9 12 18

Hrs since GFS 2 0 9 6 3 9

GFS partial cycle at 09z and 21z



Radisonde verification

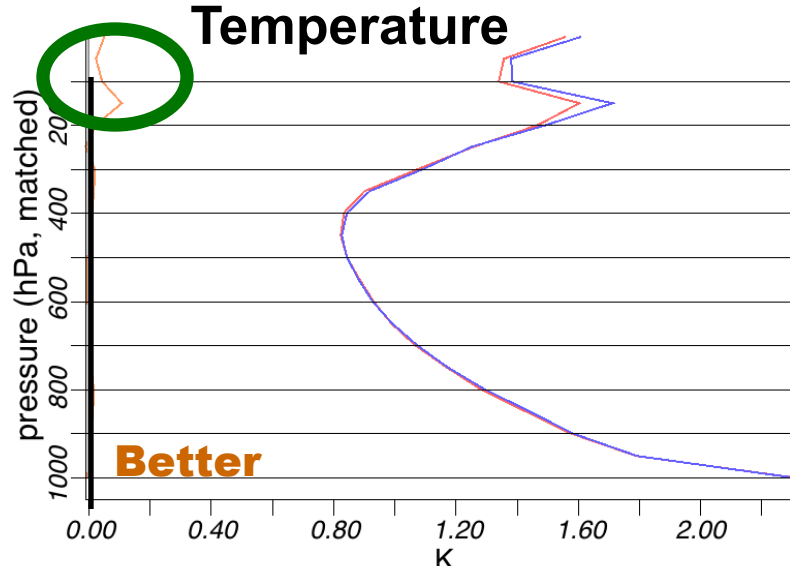


Normalize Errors

$$E_N = \frac{(\text{CNTL} - \text{EXP})}{\text{CNTL}}$$

100-1000 hPa RMS mean

6-h Forecast RMS Error

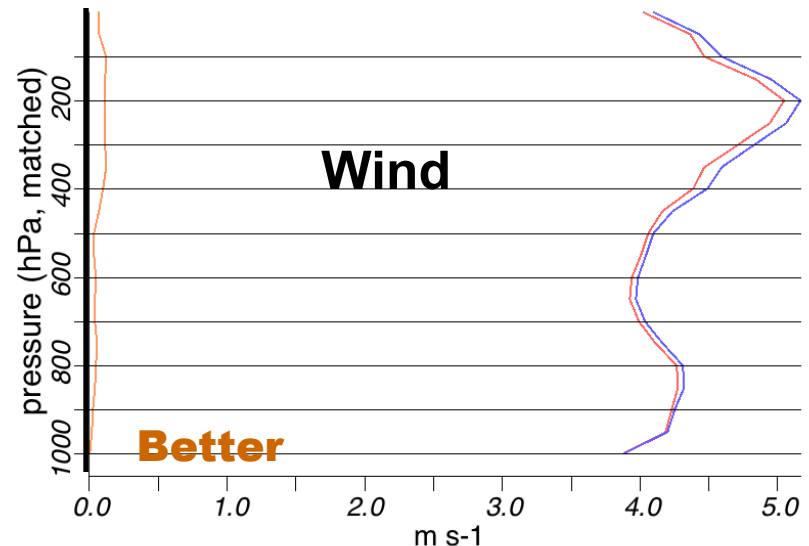
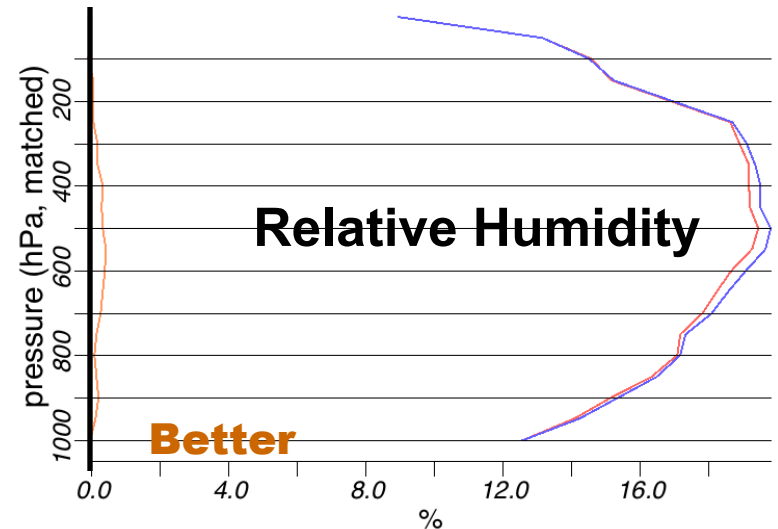


**WITH radiance
(RARS included)**

NO radiance

upper-air verification

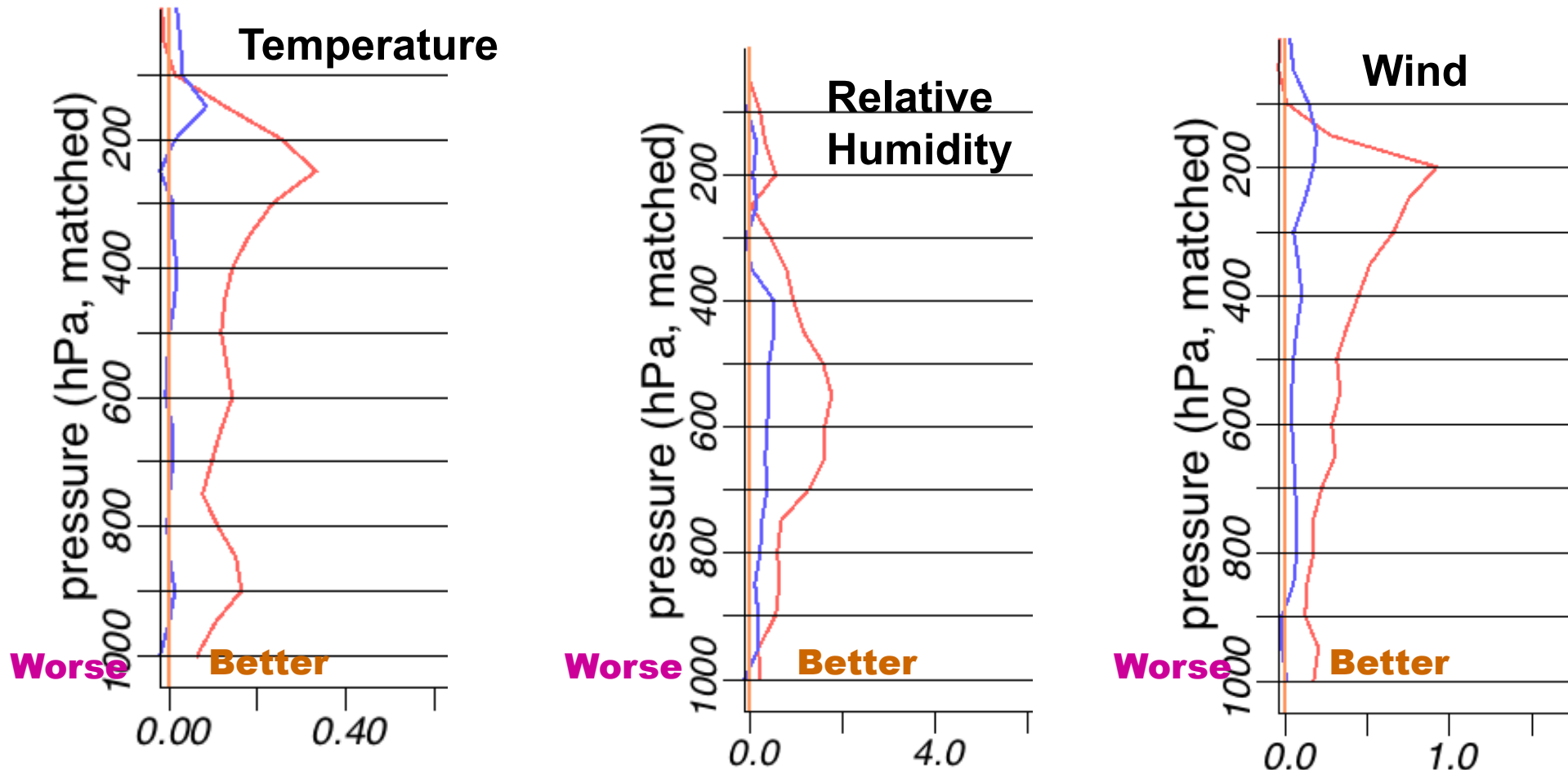
Retro run one-month
(05/01/2014-05/31/2014) averaged
(real time + RARS data)



RAPv3

6-h Forecast RMS Error improvements

Comparing **radiance** vs. **aircraft** impact

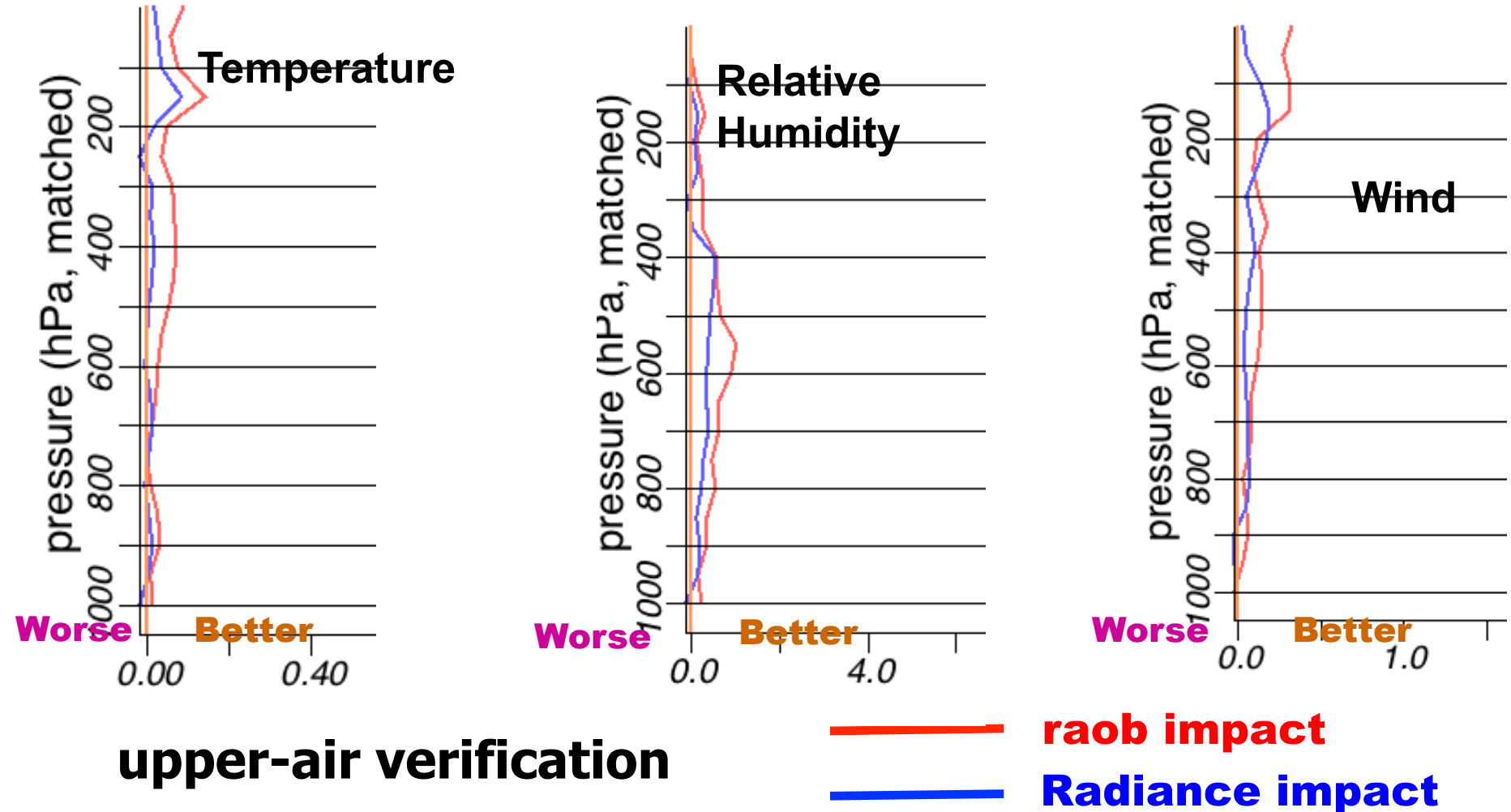


upper-air verification
Retro run
(05/15/2013-05/22/2013)

— **aircraft impact**
— **Radiance impact**
Pairwise comparison

6-h Forecast RMS Error improvements

Comparing **radiance** vs. **raob** impact



upper-air verification

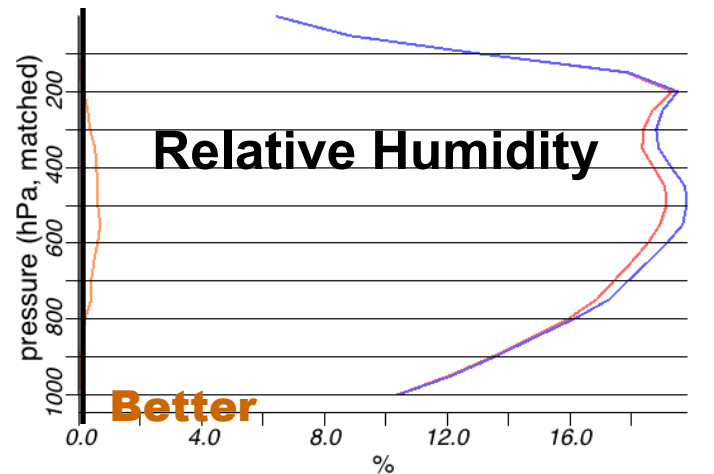
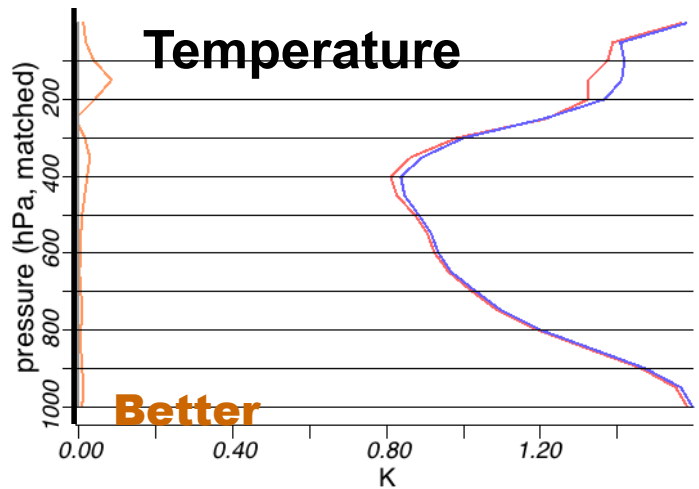
Retro run
(05/15/2013-05/22/2013)

Pairwise comparison

Real-time RAP Experiments

- **Real-time** RAP hybrid systems (**RAPv3**) on Zeus:
 - 1-h cycling with partial cycle
 - real-time data (including RARS data)
- **3-month time period** (*10 July-10 Oct., 2014*)
- **NO radiance run**
 - conventional data only
- **WITH radiance run**
 - conventional data + all radiance updates in RAPv3

6-h Forecast RMS Error

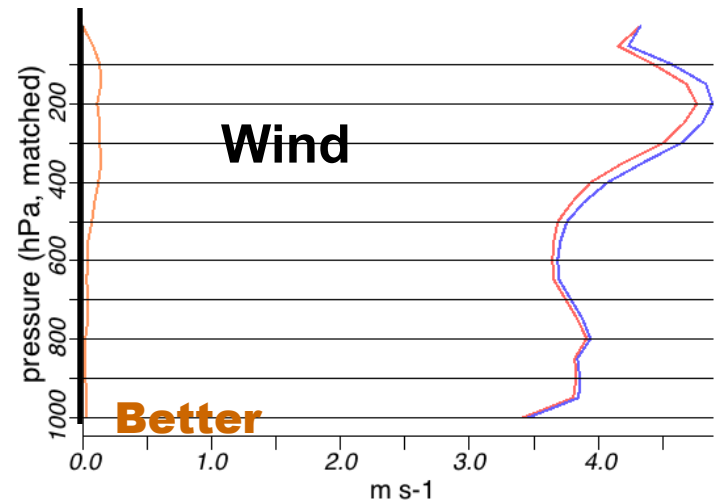


**WITH radiance
(including RARS)**

NO radiance

upper-air verification

Real-Time 3-month averaged



RAPv3

RAP-radiance assimilation summary

- A series of radiance updates have been tested at GSD and will be implemented on operational RAPv3 in mid-2015
- From one-month retrospective and 3-month real-time experiments, using the RAPv3 radiance updates,
 - 1-1.5% positive impact has been seen for temperature, moisture, and wind for all forecast hours
 - Radiance impact much less than aircraft, slightly less than raob impact



RAP-radiance assimilation summary

- Direct-readout data especially important to hourly RAP
 - Reduces data latency (necessary for RAP/HRRR)
 - RAP system will get much more real-time radiance data by using RARS data
 - daily averaged observation number increased from 6% to 41%
 - hourly averaged observation number increased from between 0-26% to 10-64%



Future work

- Include more direct readout data in real-time RAP and continue to test and evaluate their impact in RAP
- New data (related with direct readout data)
 - ATMS and CrIS from S-NPP
 - IASI from METOP-A/B
 - ABI from GOES-R
- Increase RAP model top and model levels



